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# System of 7MeV-Proton Linac

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The construction of a 7MeV-433MHz proton linac was started in 1986. The accelerator was installed in a new building on the Uji campus of Kyoto University in 1988. The accelerator system, the RF control system and the vacuum system are described.

KEY WORDS: RFQ linac/ Alvarez linac/ Proton linac/ RF control/ vacuum/

## 1. INTRODUCTION

A new accelerator was constructed at a new accelerator laboratory building of Institure for Chemical research (ICR) on the Uji campus of Kyoto University. It consists of a 2 MeV-RFQ linac[1,2] and a 7 MeV-Alvarez DTL[3]. The main specification is shown in Table 1. The operating frequency is 433.3 MHz throughout the system.

Table 1

| | |
|---|---|
| Ion source | |
| multicusp field type | proton 50 keV |
| Accelerating structure | |
| four vane RFQ | 50 keV～2 MeV |
| vane length | 2195 mm |
| cavity inner diameter | 170 mm |
| characteristic radius | 3 mm |
| min. bore radius | 2 mm |
| intervane voltage | 80 kV |
| transmission efficiency | 95% (at 30 mA) |
| DTL (Alvarez) | 2 MeV-7 MeV |
| cavity length | 1868 mm |
| number of drift tubes | 28 |
| focusing Q magnet | NdB iron permanent magnet |
| RF power source | |
| frequency | 433.3 MHz |
| peak power (for each tube) | 1 MW |
| repetition rate | <180 Hz |
| duty factor | 1 % |
| Klystron | Litton L-5773 |

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The frequency is about twice higher than conventional DTLs and the size is about a half of them.[4] Klystrons are available for such higher frequency as high power RF sources. A higher energy accelerating cavity is planned to be connected after the DTL in the future. The operating frequency of the high-$\beta$ structure should be 1.3 GHz, which is three times higher than that of the low energy part, and it allows the simultaneous acceleration of both positive and negative ions.

The area of the new accelerator building space is 2650 m$^2$ in total, and the shielded

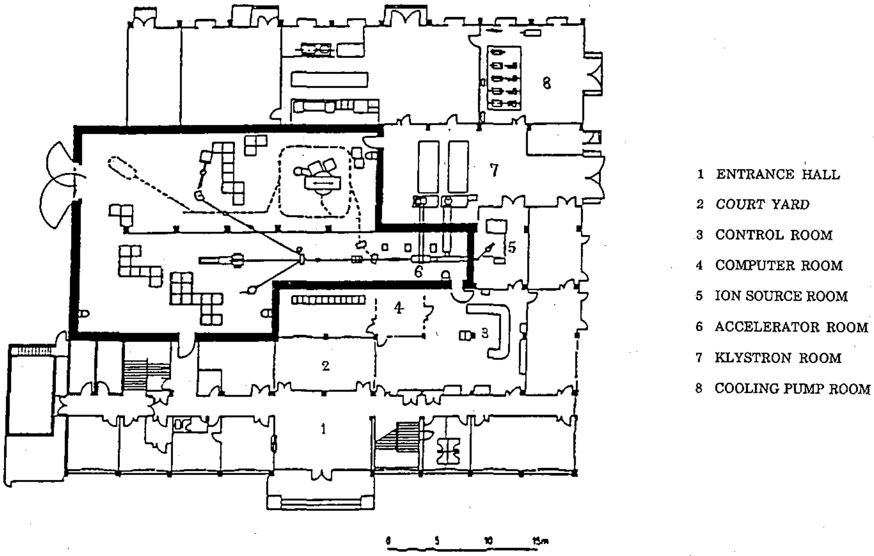


Fig. 1. Plan view of the Accelerator Laboratory (1F)

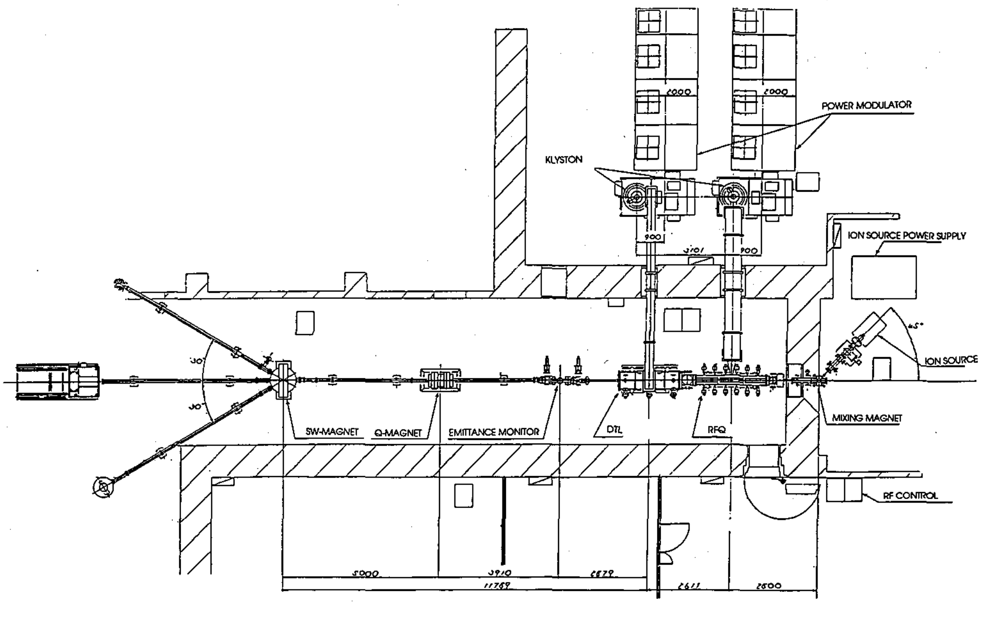


Fig. 2. Layout of the accelerator system.

area surrounded by 1 meter thickness wall is 600 $m^2$. The compact size of the accelerator saves enough area for future developments as shown in Fig.1. The Fig.2 shows the layout of the main part of the accelerator system.

## 2. ACCELERATOR SYSTEM

### INJECTOR

A multicusp-field ion source is used to produce 50 kV $H^+$ ion. The arc voltage of the ion source is switched for pulsed operation of up to 10% dutycycle. The designed peak beam current is 60 mA. There is an einzel-lens and a pair of x-y steering electrodes after a 50 kV accelerator column. For the future simultaneous acceleration of positive and negative ions, the low energy beam transport (LEBT) has a 45 degree mixing magnet. After the mixing magnet, a solenoidal focus coil is used to match the beam phase space configurations to the RFQ.

### RFQ

The 4-vane RFQ is operated at the frequency of 433.3 MHz. The outer wall and the vanes are made of CrCu (Cr 0.75, Zr 0.08) which has 80% electric conductivity of Cu and 80% Young's modulus of stainless steel. The vane tips are machined with a concave cutter and have a constant curvature along the axial direction. Each vane has a 20 mm diameter cooling channel in it. For field distribution tuning, 6-plug-tuners are installed in each quadrant. The designed intervane voltage is 80 kV. The RF power is generated by an 1MW-peak-power Klystron L-5773, and coupled through WR-2100 waveguide by a loop into the RFQ cavity after a waveguide-to-coaxial line transition. The measured Q value is 5000, while SUPERFISH result is Q=6600.

### Beam Matching Section

Permanent quadrupole magnets are used to focus the output beam from RFQ. Four of them are installed before a buncher and another four quadrupole magnets are installed before the DTL cavity. The buncher is needed to match the beam to the longitudinal acceptance of the DTL. Beam monitors will be installed in this section to investigate the output beam from the RFQ.

### DTL

The tank is made of standard Cu, and the drift tubes are made of OFC. The stems are made of CrCu. The drift tube diameter is 55 mm and the bore radius is 5 mm. Permanent quadrupole magnets are installed in the drift tubes to focus beams. Each drift tube is supported by a stem from the bottom plate which is demountable from the tank. The 28 drift tubes were aligned on the plate before installation into the tank. The 5 tuners of 10 cm diameter are installed in the tank. Two of them are fixed, and three are tunable. The klystron L-5773 is also used as the power source and the power is coupled by a 5 cm width slot on the tank top. The slot length is about 15 cm. The coupling Q value is shown in Fig.3 as a function of slot length. The

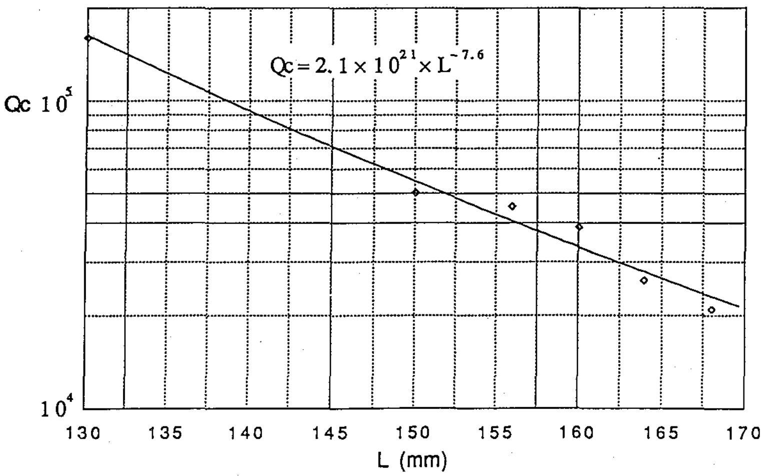


Fig. 3. *Coupling Q of DTL as a function of slot length*

unloaded Q is about 38000. The average accelerating field is 3MV/m.

## 3. RF CONTROL SYSTEM

A schematic block diagram of the RF control system is shown in Fig.4. The base RF is generated by an SSG HP865B and the operating frequency is phase locked to the RFQ cavity resonance frequency. The RF phase of each cavity is also phase locked to the base SSG phase. For resonance control, the tuner can be adjusted by phase

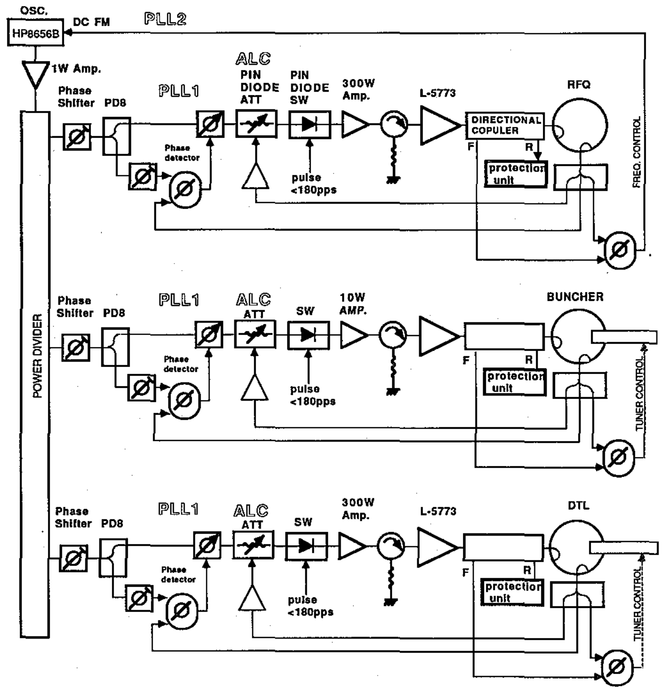


Fig. 4. RF control system

difference between the input RF and the RF in the cavity. The relative phase of each cavity is adjustable. Each klystron needs up to 300W RF input to generate 1MW RF, and the 300W RF power is generated by an FET amplifier respectively. To keep the RF voltage constant, the input power to the klystron is controlled by AGC circuit. ECL D-flipflops are used for the phase detectors, and the detecting range is ±180 degrees.

## 4. VACUUM SYSTEM

Fig.5 shows a block diagram of the vacuum system. A 500-liter/s turbo molecular pump (TMP) is used for the ion source, and a 150-liter/s TMP is installed at the LEBT section. Both turbo pumps have the ordinary bearing system.

Because of the poor vacuum conductance through the RFQ tank, the pumps are installed at both the entrance and exit side. To evacuate the RFQ tank, a 270 liter/s turbo molecular pump is installed at the entrance side, and a 700-liter/s cryo pump (2400-liter/s for $H_2O$) is also installed at the RFQ-DTL connecting section to evacuate from the RFQ exit side. At the DTL thak, a 400-liter/s TMP is installed. Both turbo pumps are oil free with magnetic floating rotars. A 160-liter/s ion pump is also installed at each RF feeder. One is at the bottom of the waveguide-coax transition of the RFQ and another is at the coupling slot of the DTL.

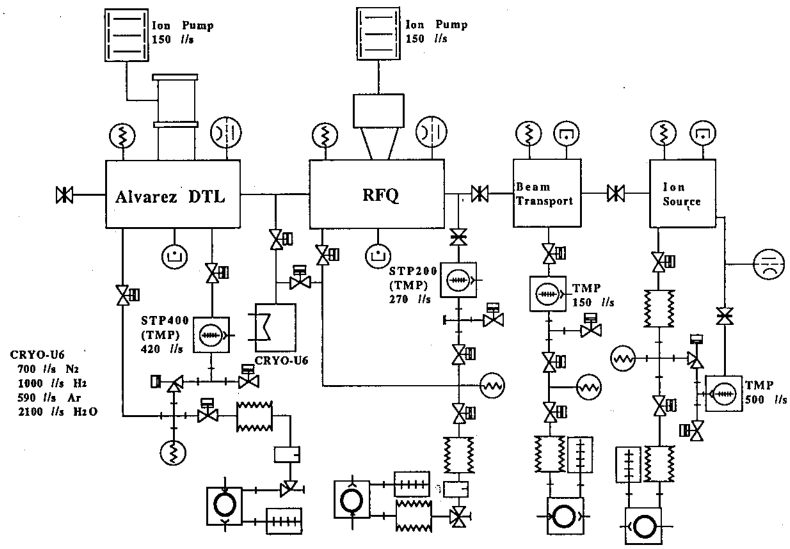


Fig. 5. Vacuum system

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